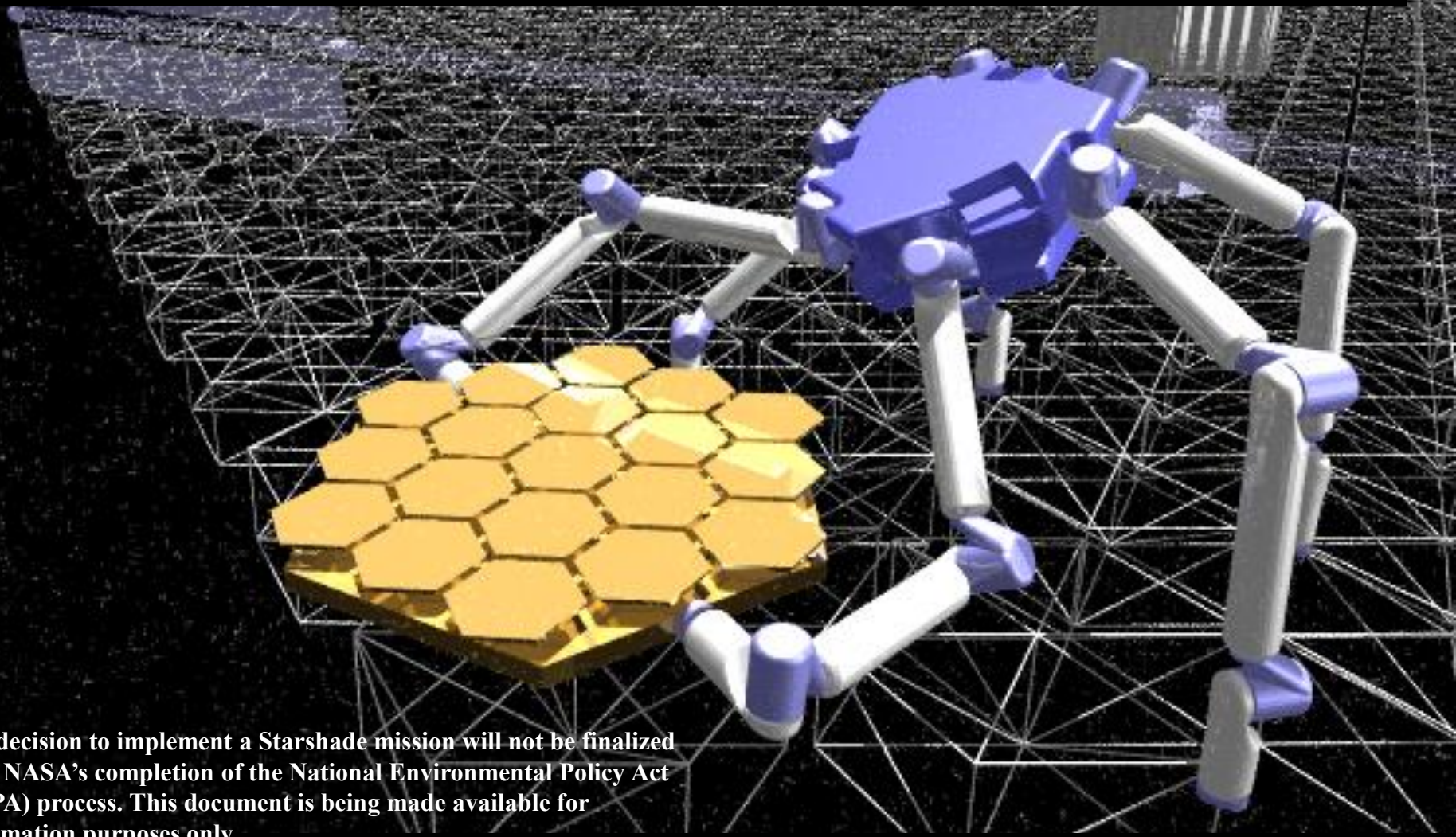
Jet Propulsion Laboratory
California Institute of Technology

In-space Assembly of Large Telescopes for Exoplanet Direct Imaging

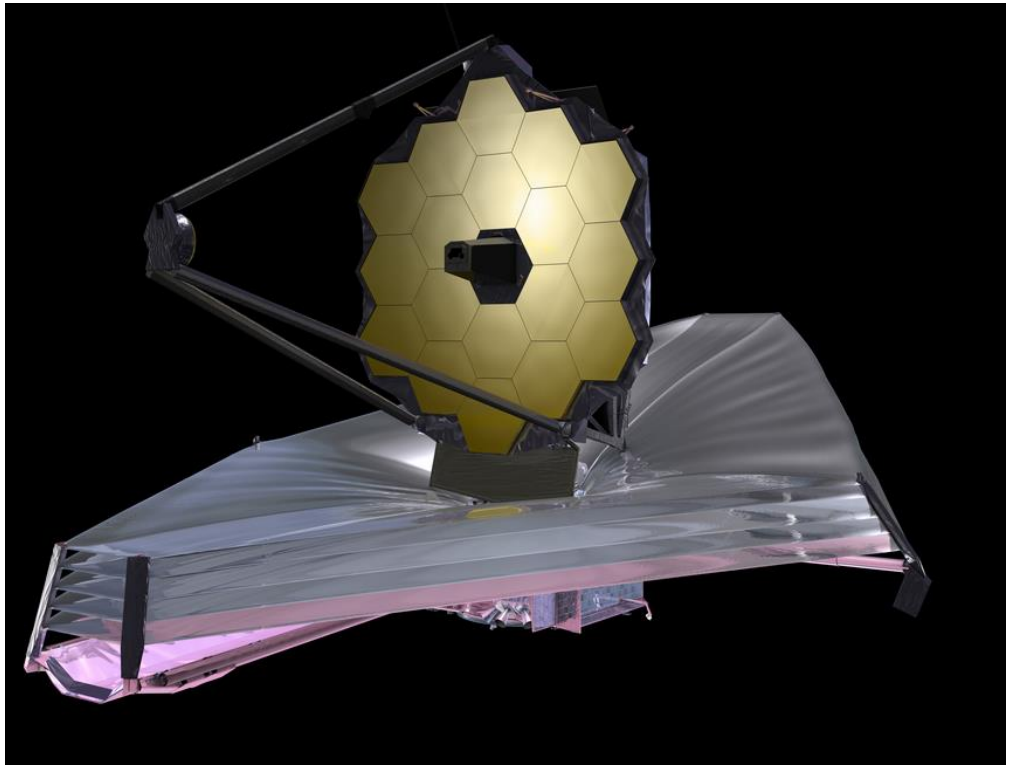
Nick Siegler, Chief Technologist, NASA Exoplanet Exploration Program (JPL/Caltech)
Rudranarayan Mukherjee, Robotics Technologist (JPL/Caltech)



The decision to implement a Starshade mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

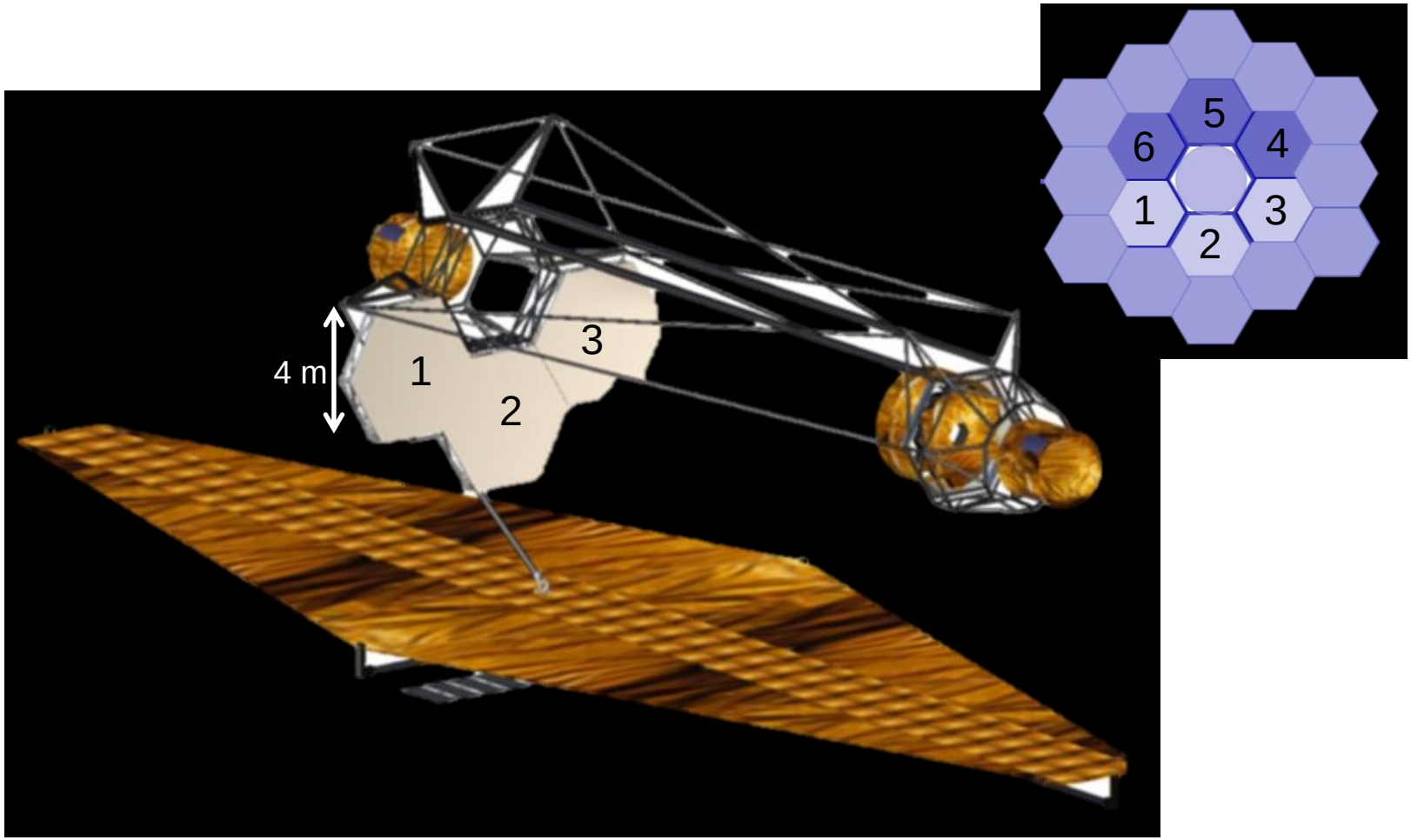
Aperture size limited by launch vehicle

Future science needs will require increasingly large telescopes



In-Space Large Aperture Telescope Assembly

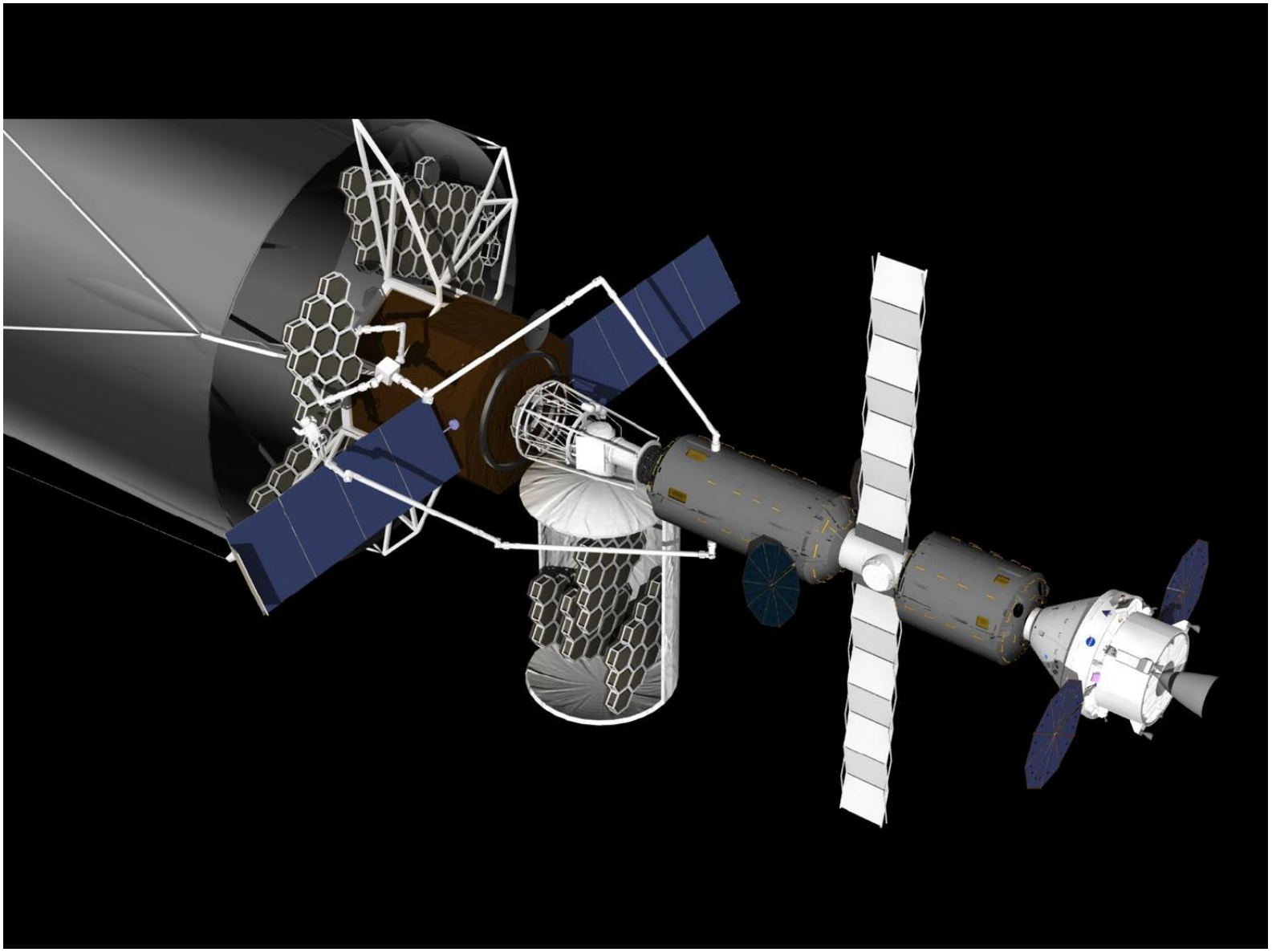
Evolvable Space Telescope (NGAS)



Polidan et al. 2016

In-Space Large Aperture Telescope Assembly

Using the Deep Space Gateway (cis-Lunar orbit) to assemble



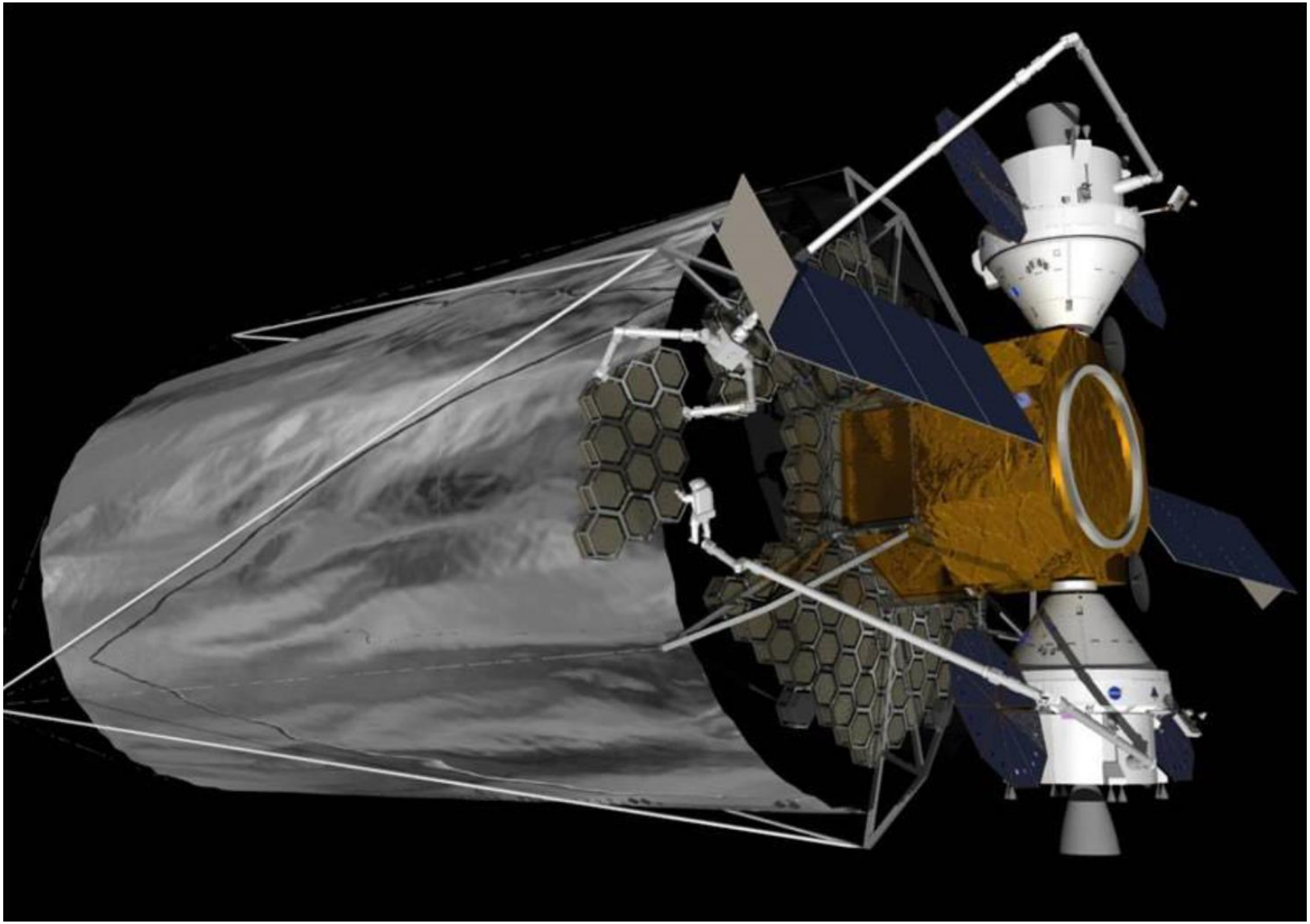
In-Space Large Aperture Telescope Upgrade

Telescope returns from ESL2 for servicing at EML1

Courtesy: Future In-Space Operations (FISO) working group (2007)

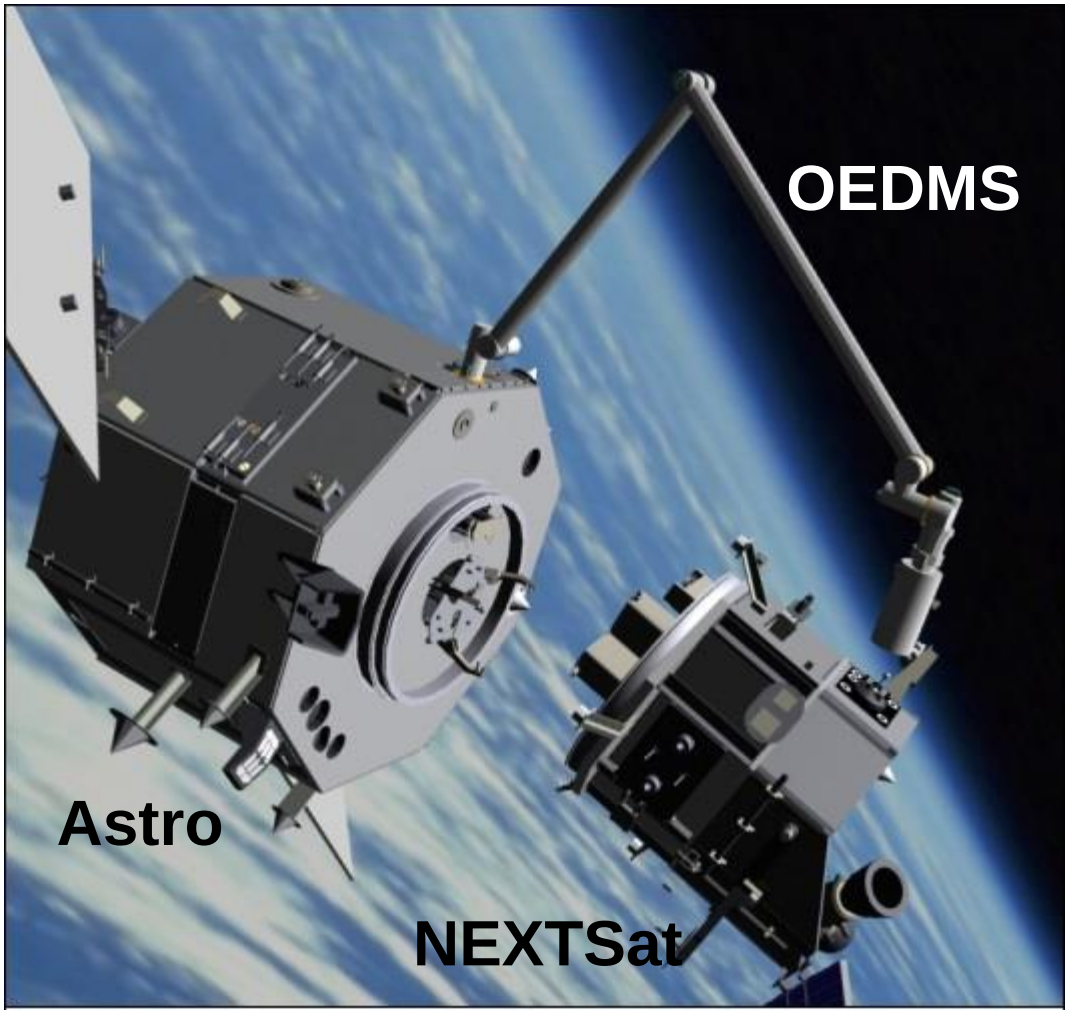
In-Space Large Aperture Telescope Assembly

Free-fliers (e.g. Orion) and assembly module docked to spacecraft bus



NASA GSFC

DARPA Orbital Express (2007)



DARPA/Boeing/MDA/Ball Aerospace

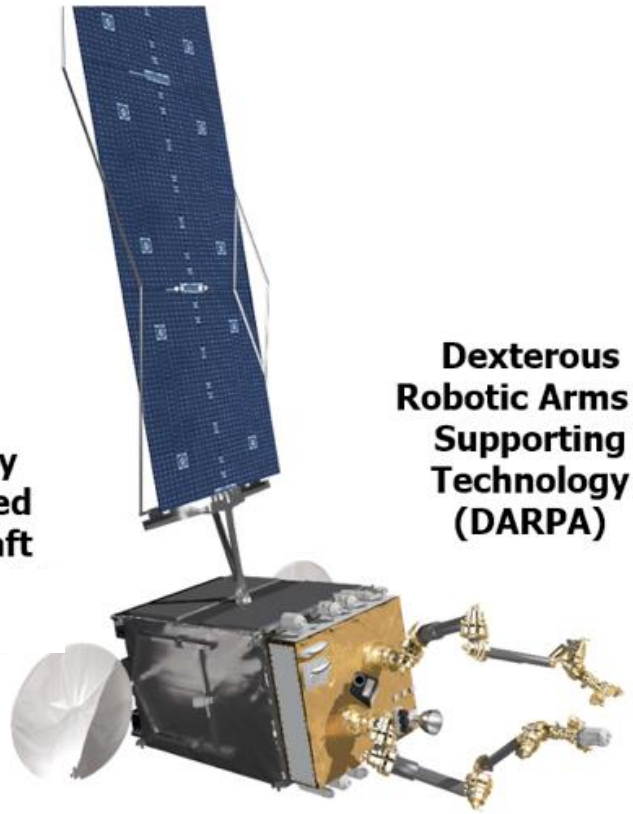
- Multiple autonomous berthing and docking maneuvers

In-space firsts:

- Transfer of fuel
- Transfer of a battery through the use of 3-m long robotic arm

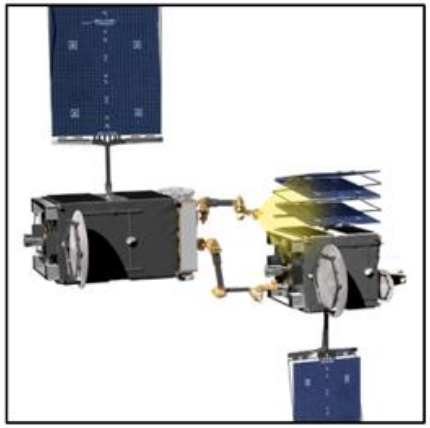
Robotic Servicing Missions

DARPA Robotic Servicing of Geosynchronous Satellites (RSGS)

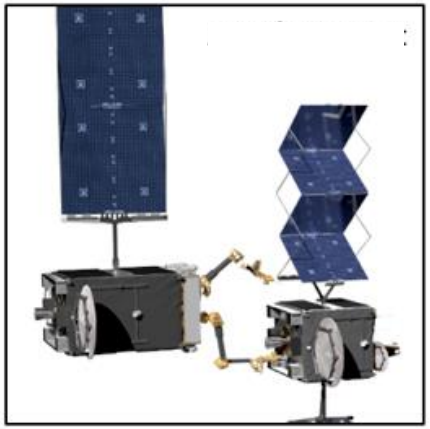


Privately Developed Spacecraft (SSL)

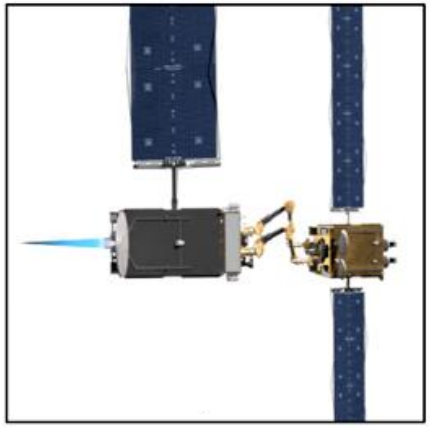
Dexterous Robotic Arms & Supporting Technology (DARPA)



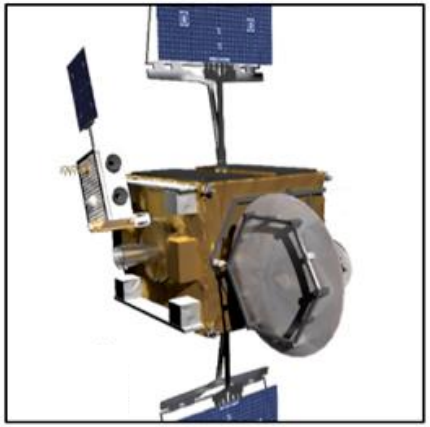
High-Resolution Inspection



Anomaly Correction



Cooperative Relocation

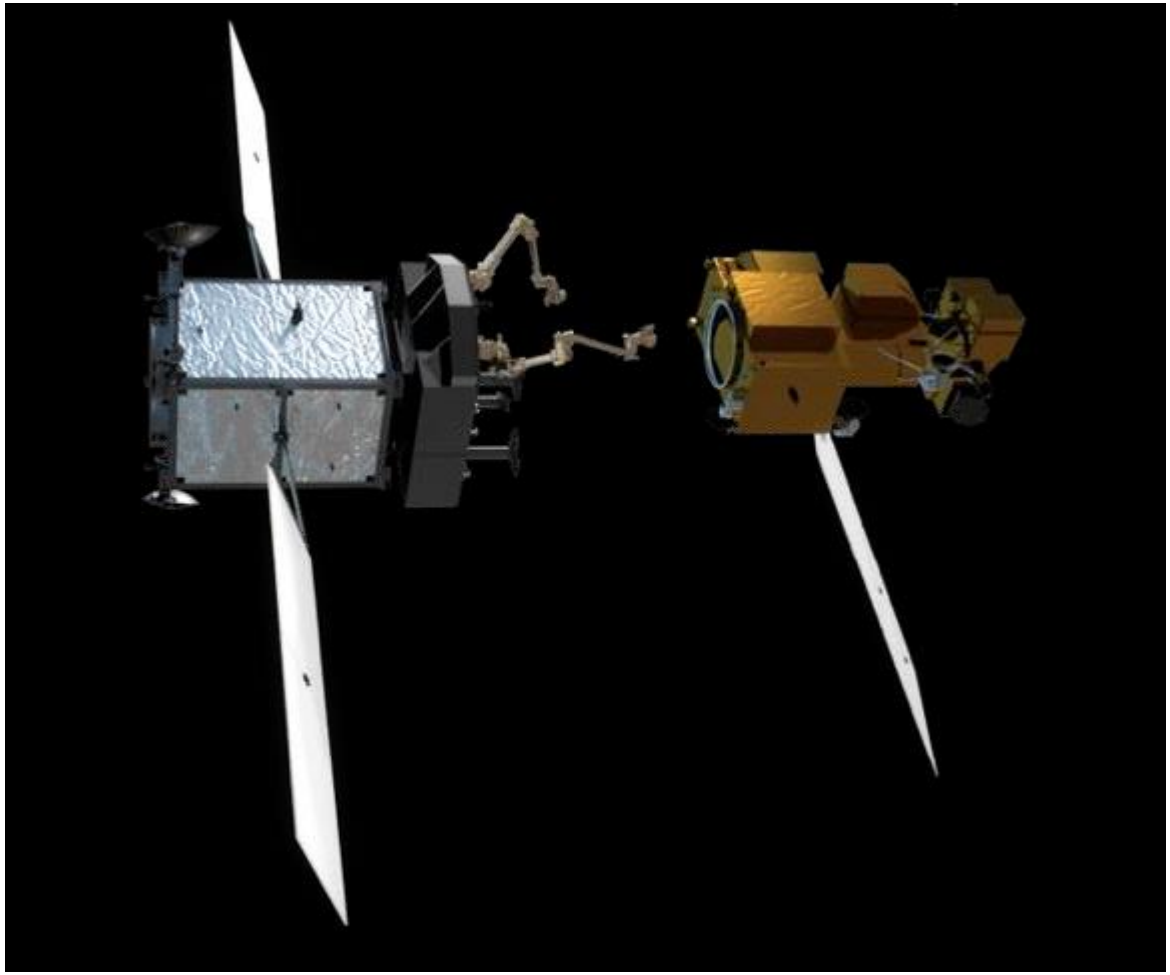


Upgrade Installation

Robotic Servicing Missions

Restore-L (NASA GSFC)

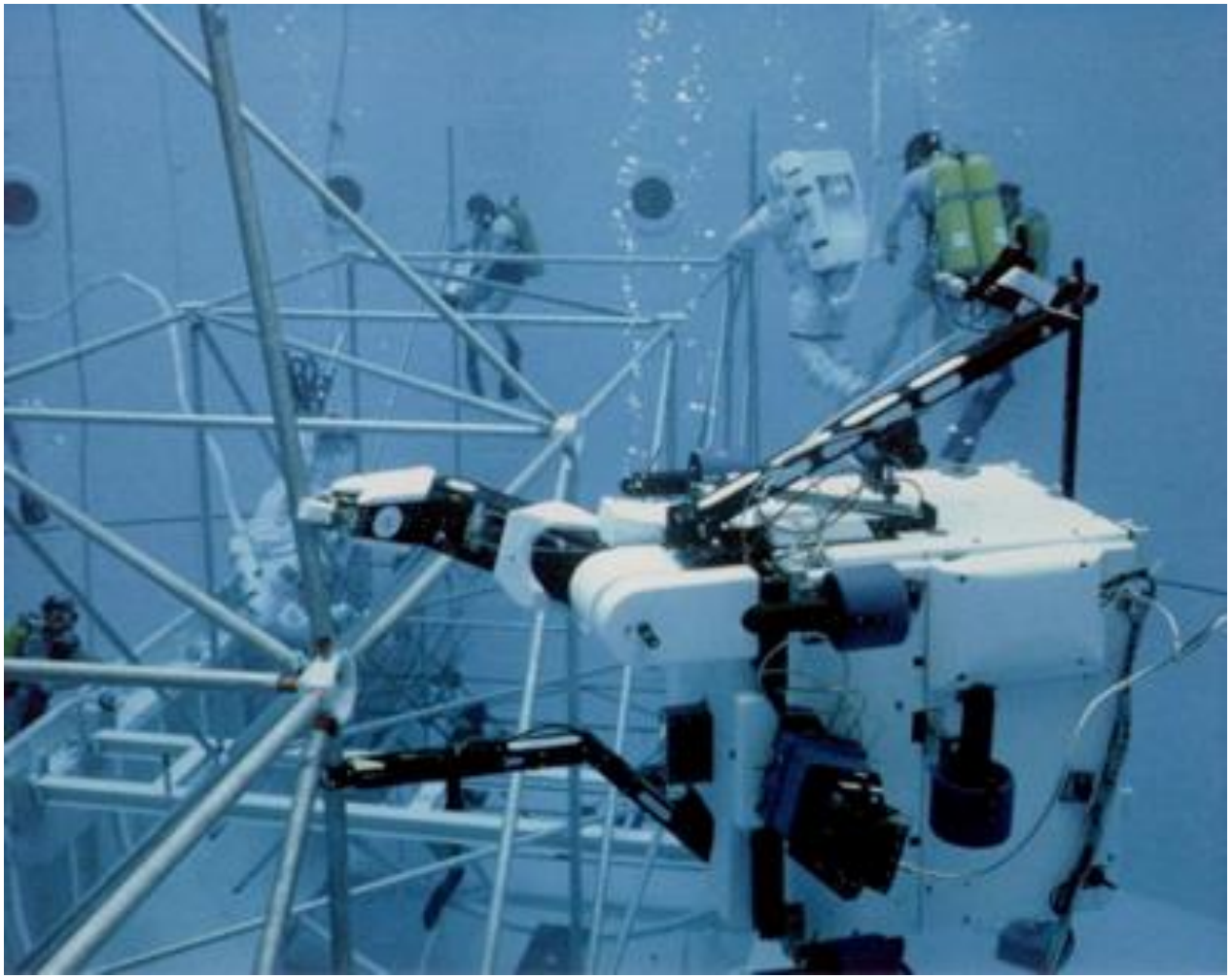
- **Refueling an existing satellite (Landsat 7)**
- **Future capability demonstrations:**
  - Observatory repair
  - Instrument replacement
  - On-orbit assembly and manufacturing



NASA GSFC

Beam Assembly Teleoperator (1983)

Neutral buoyancy robot (Space Systems Laboratory)



Accumulated a large database comparing human and robot performance in space

Demonstrated the ability of robots to assist astronauts during EVA excursions

http://www.ssl.umd.edu/projects/rangernbv/background.html

ACCESS and EASE (1985)

Astronaut demo of large-structure piece-parts assembly

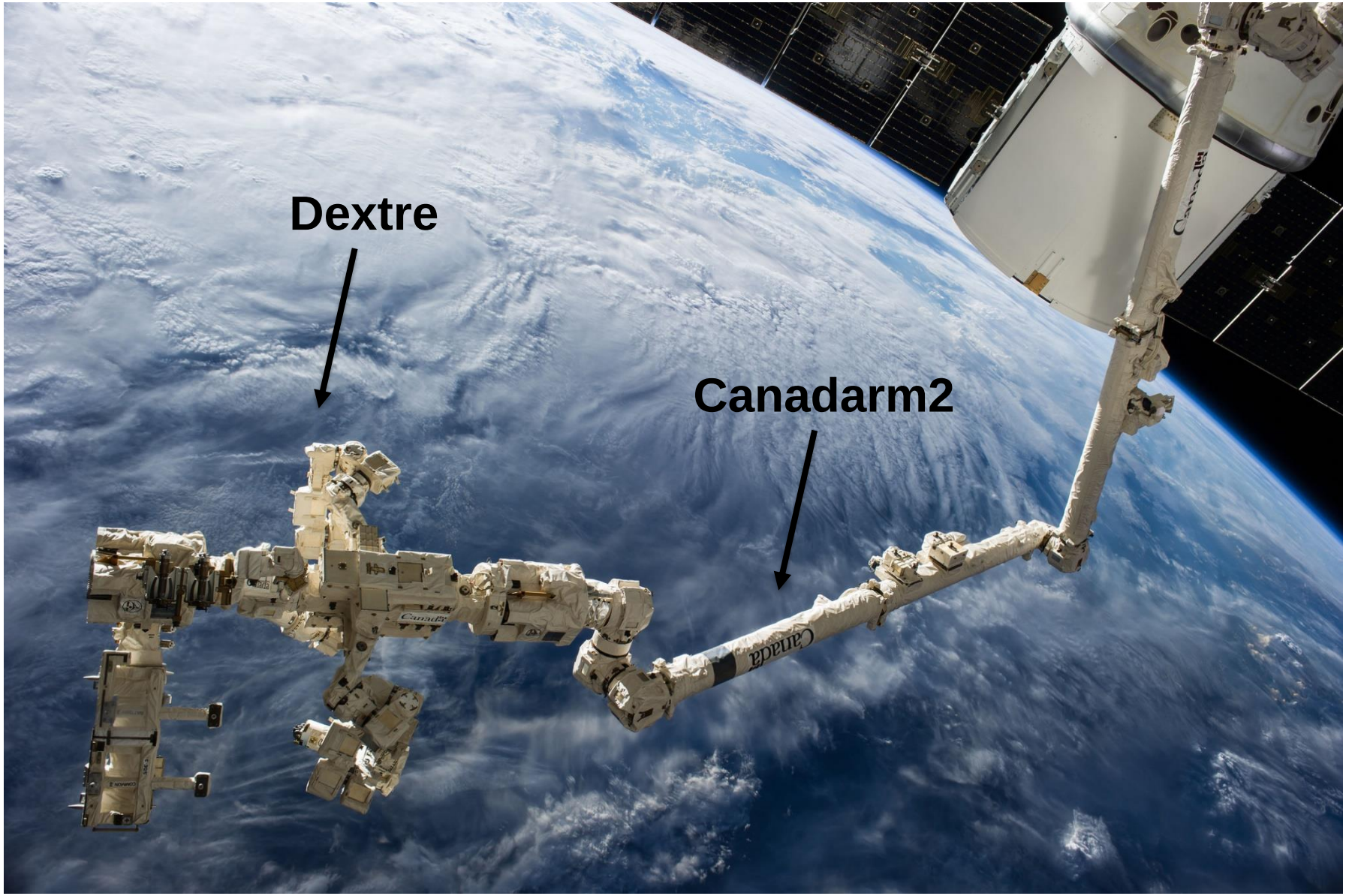
ACCESS (NASA LRC)

EASE (NASA MSFC and SSL)

https://en.wikipedia.org/wiki/EASE/ACCESS

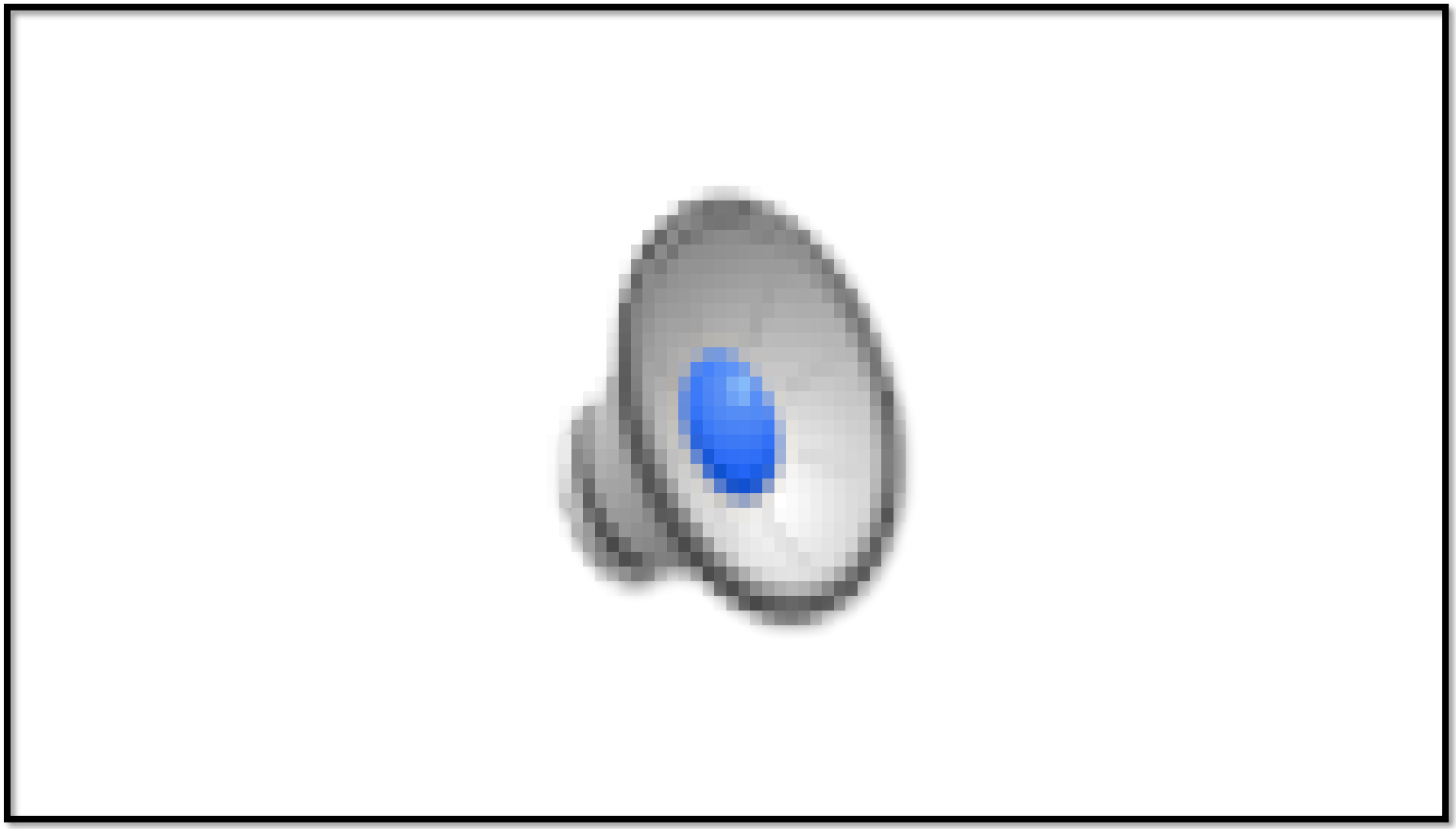
ISS Robotic Systems

Canadarm (2001), Dextre (2008)



ISS Robotic Systems

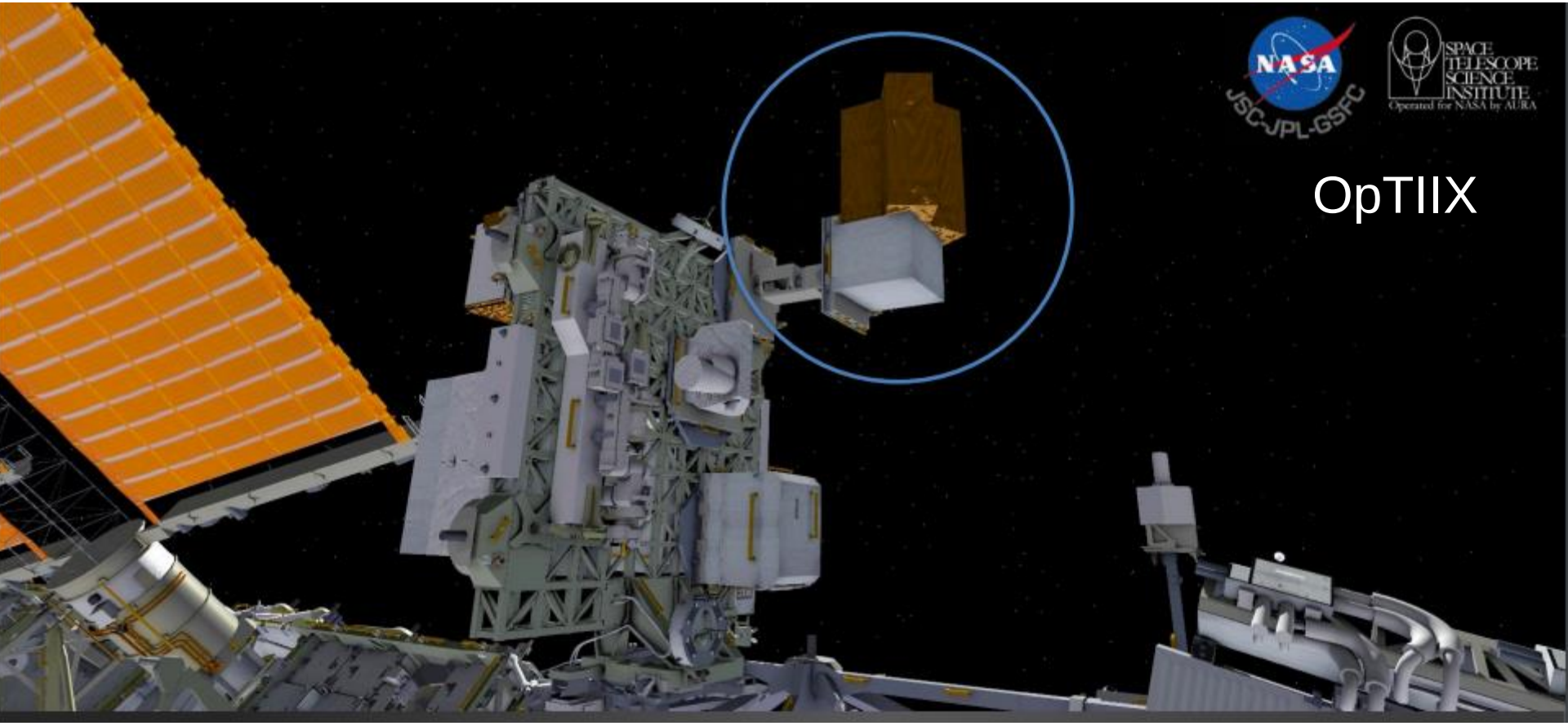
Canadarm



https://www.youtube.com/watch?v=q7N4WD4pgLQ

Optical Testbed & Integration on ISS eXperiment

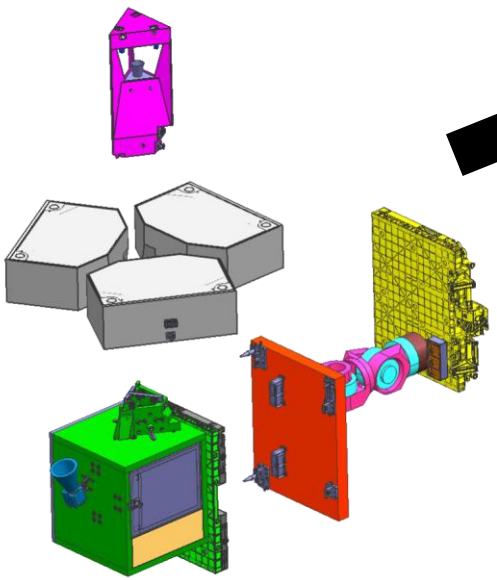
In-space assembly demo of a segmented space telescope (2012)



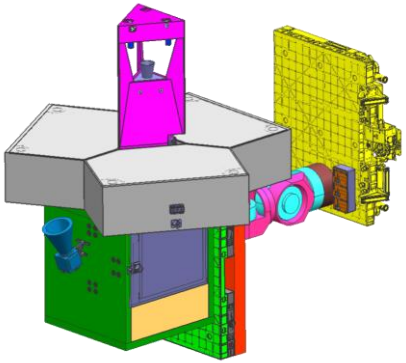
- Intended to demonstrate assembly, alignment, calibration, and operation of future space observatories
- Robotically assembled and operated

Optical Testbed & Integration on ISS eXperiment

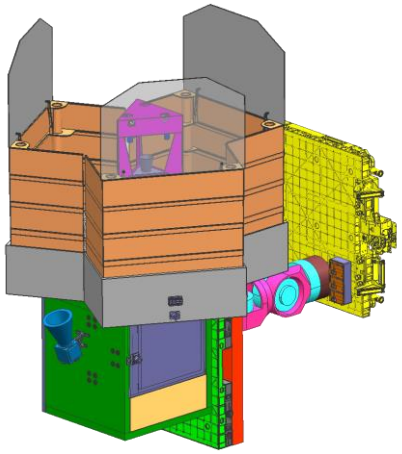
Robotically assembled and operated



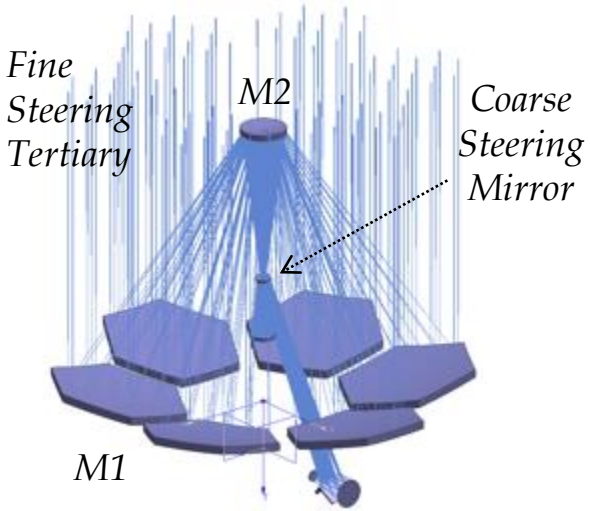
6 launch modules for assembly



Assembled modules



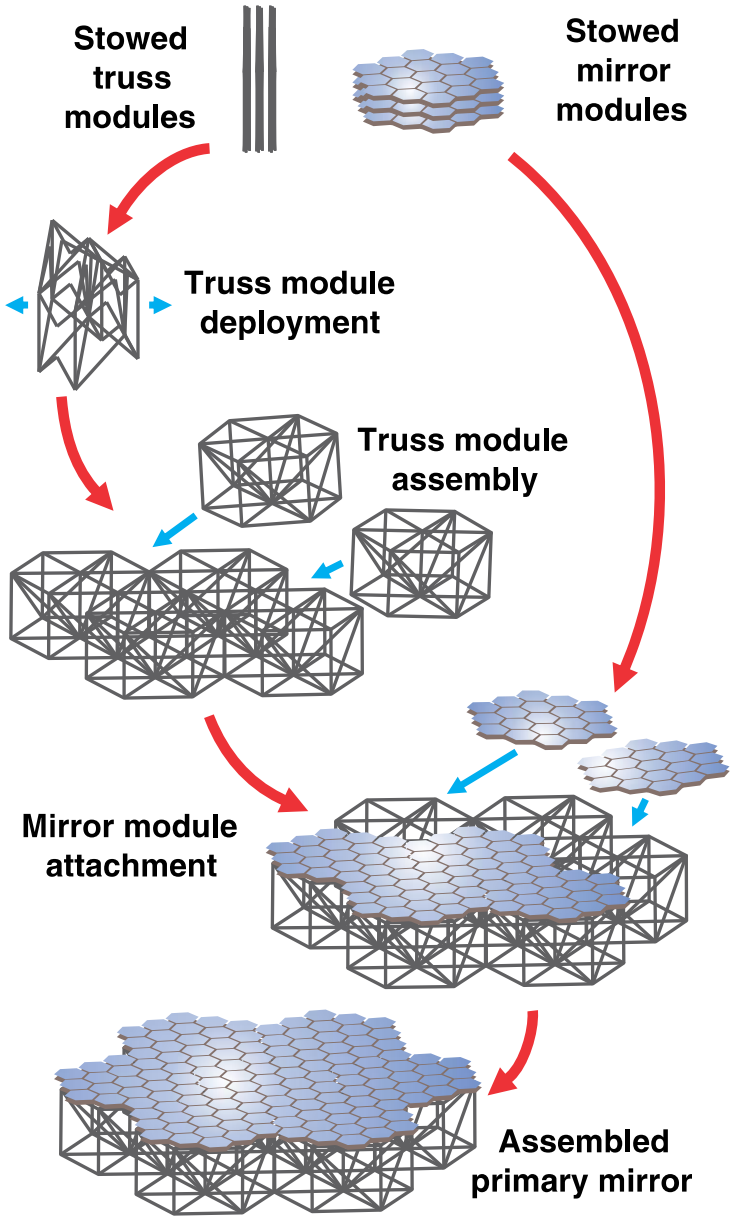
Full deployment of sunshades



3 Mirror Anastigmat Telescope (1.45m aperture)

Robotic Assembly of a Telescope

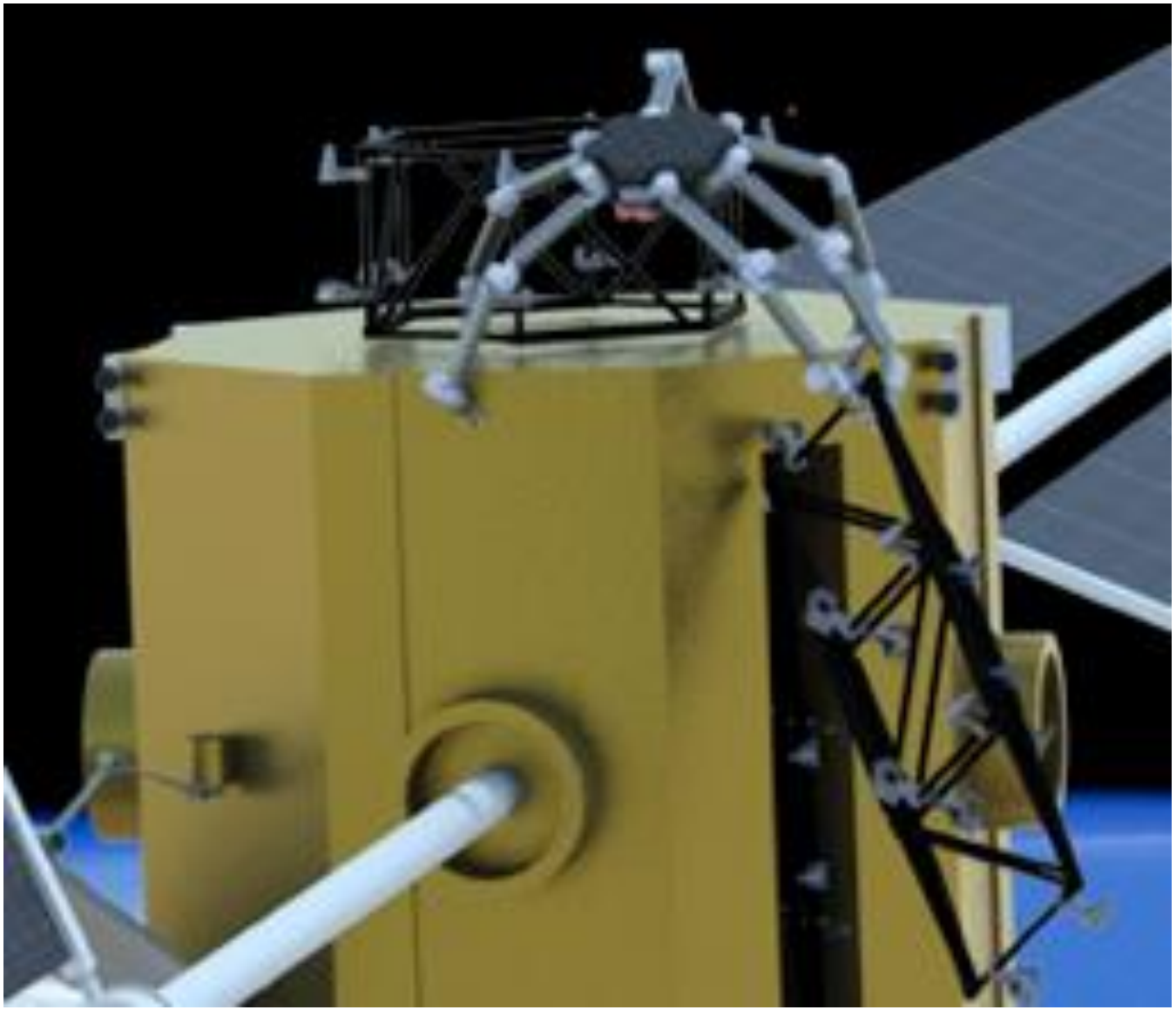
Modular deployable structure



Lee et al. 2016 (Caltech/JPL)

In Space Telescope Assembly Robotics

Multi-limbed robot



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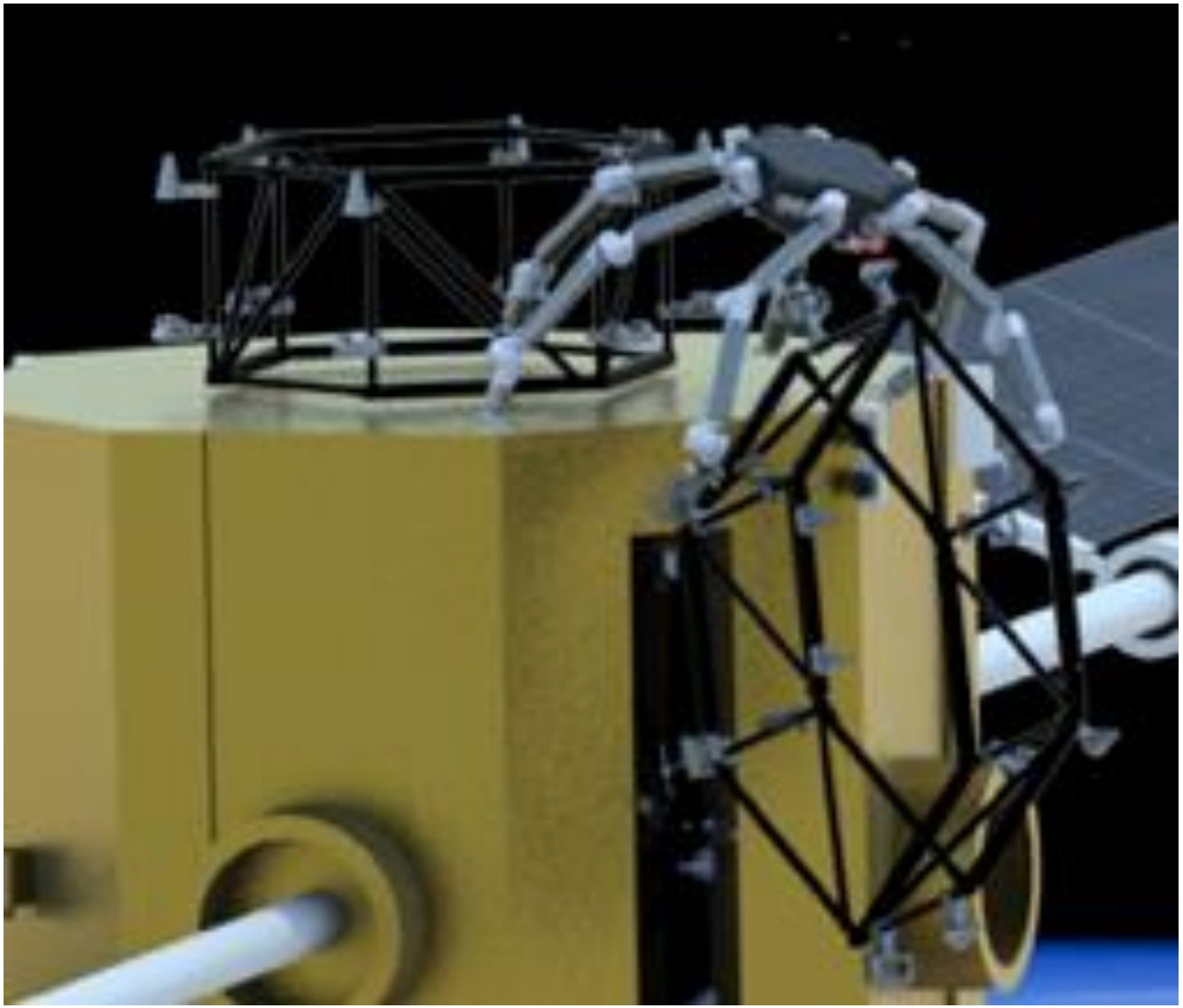

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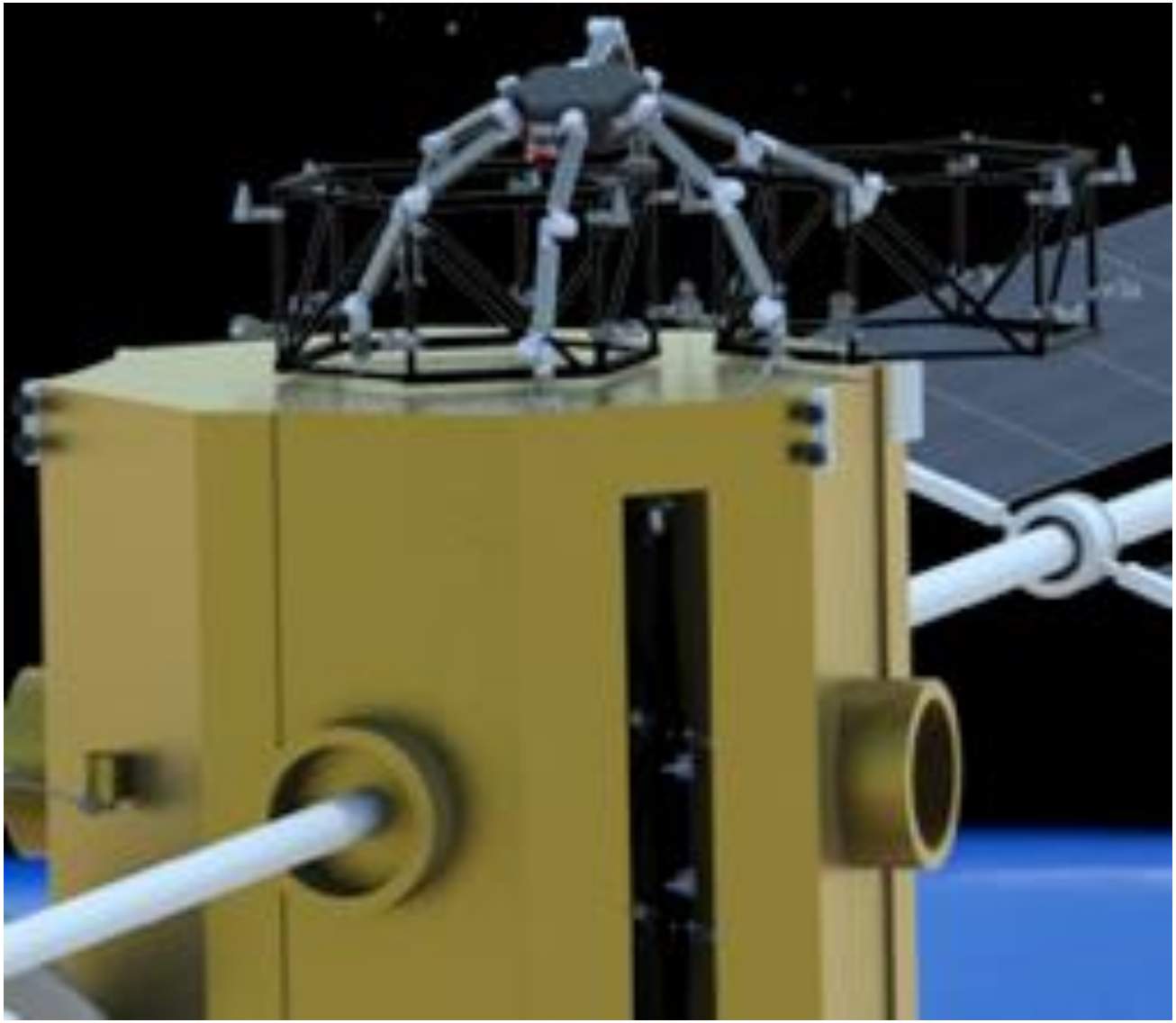

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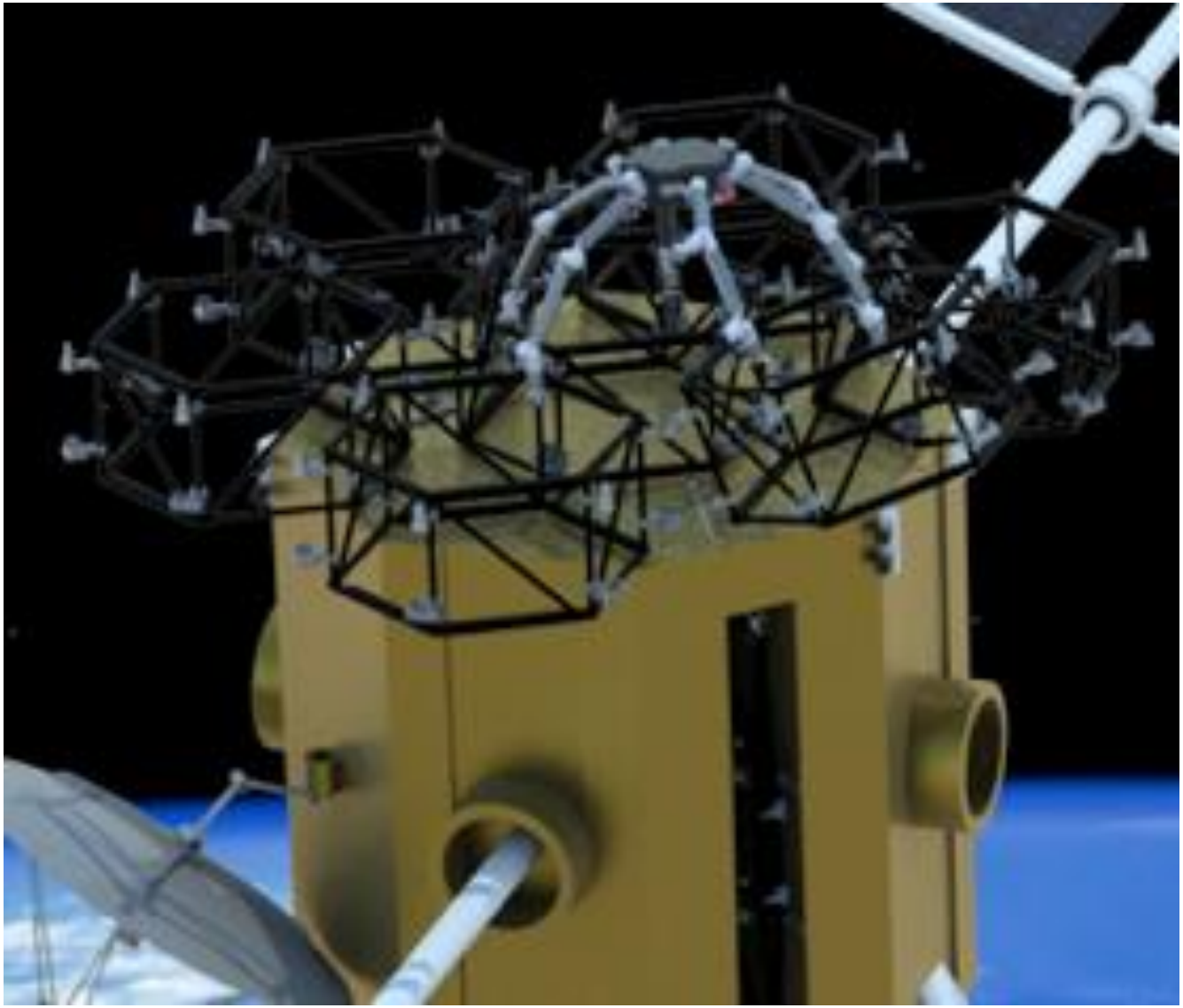

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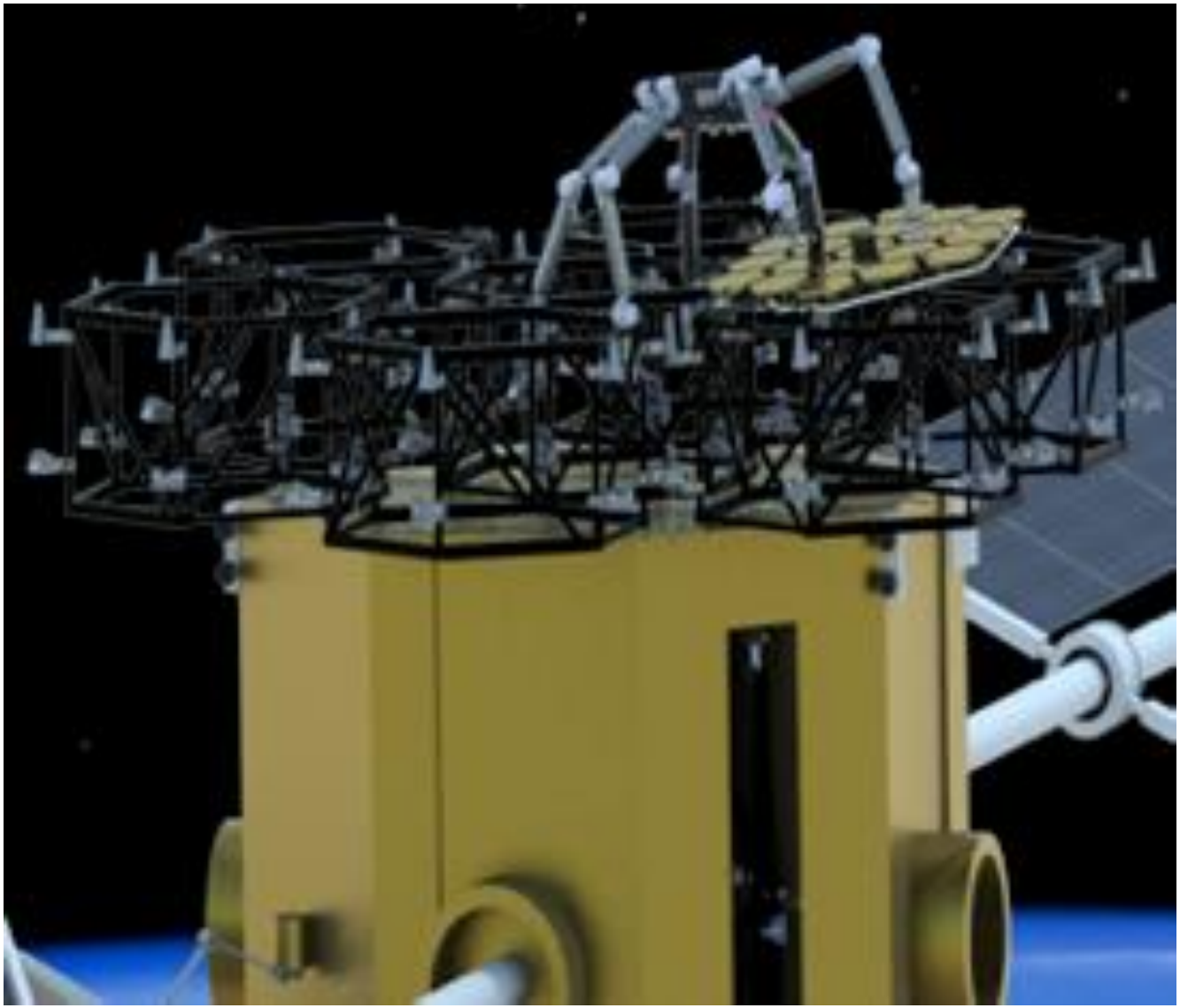

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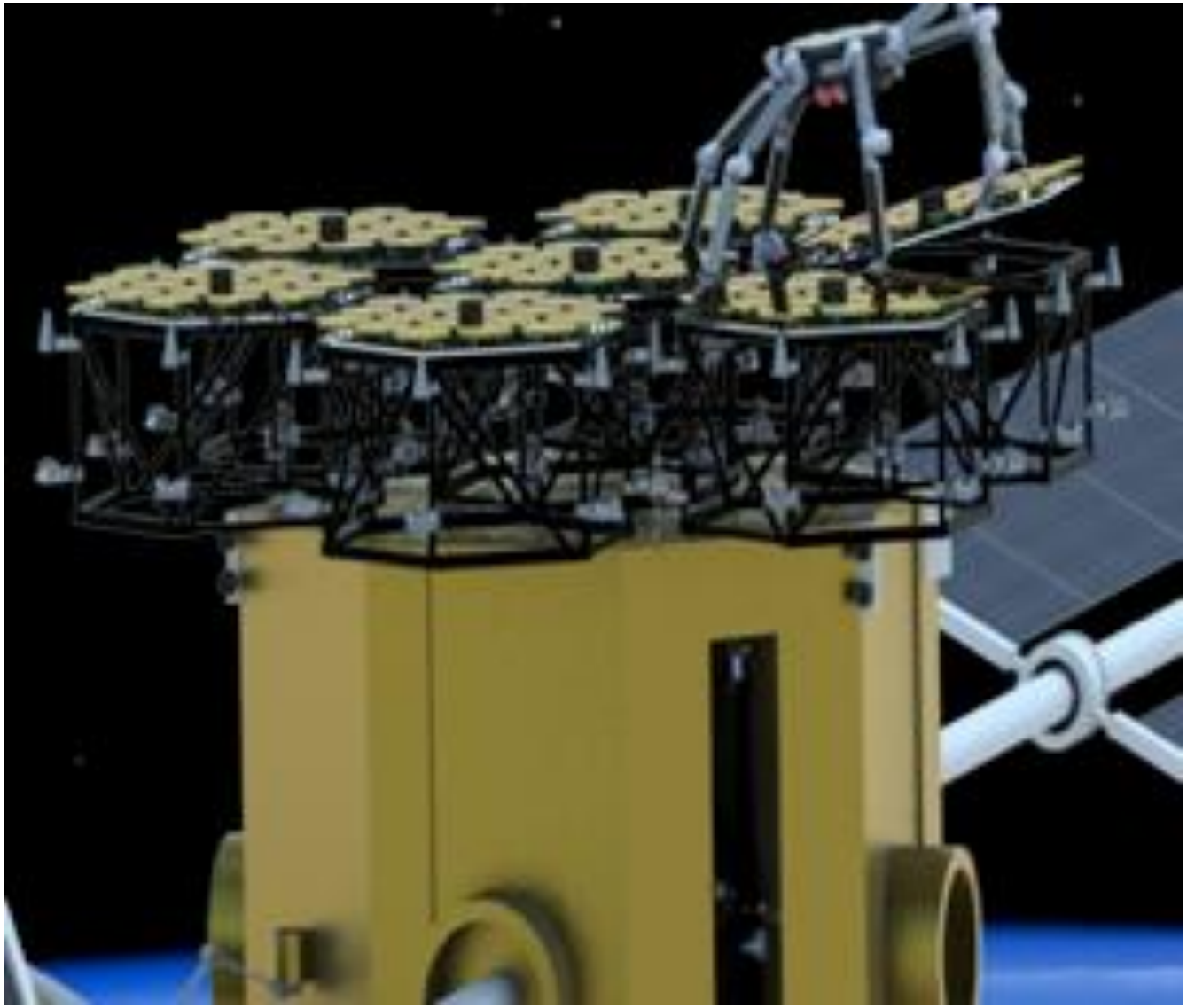
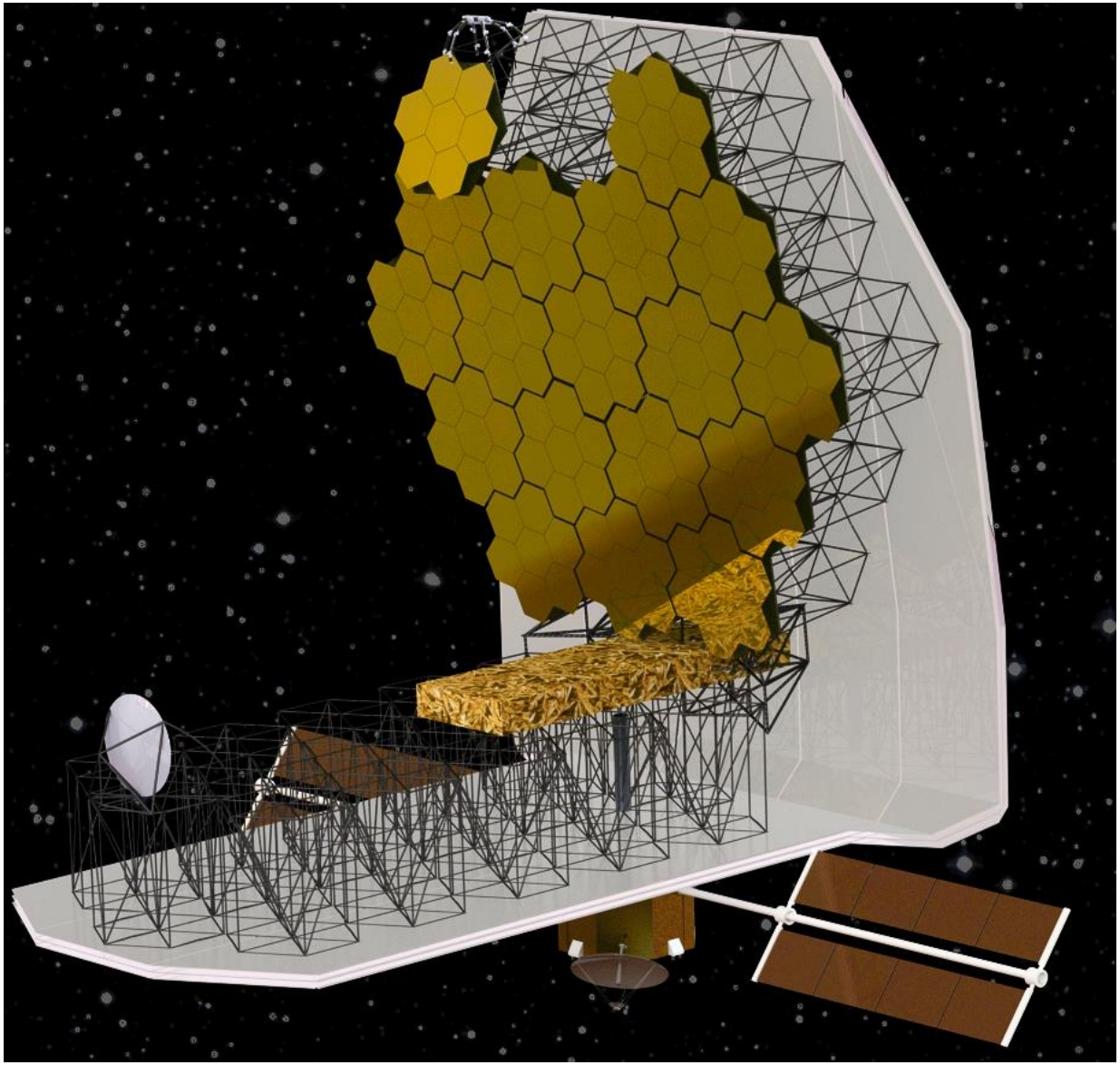


Lee et al. 2016 (Caltech/JPL)

In Space Telescope Assembly Robotics

Unobscured Ritchey-Chretien



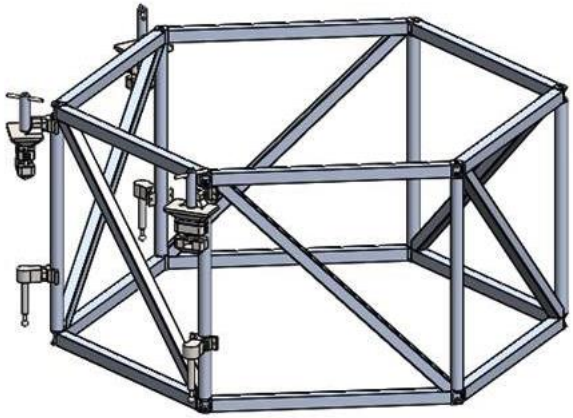
Lee et al. 2016 (Caltech/JPL)

In-Lab Telescope Truss Assembly Robotics

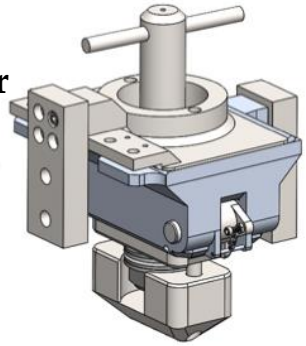
DARPA-funded JPL 3-m telescope assembly demo

Stowed DTMs

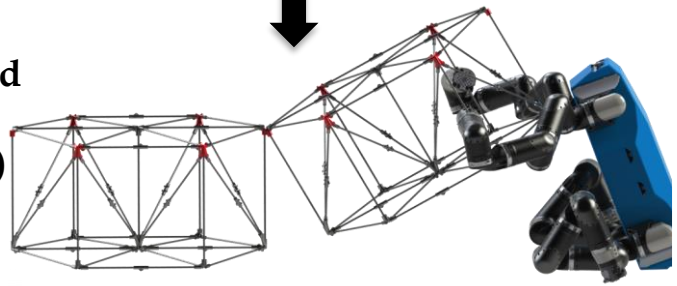
Robotically Deploy



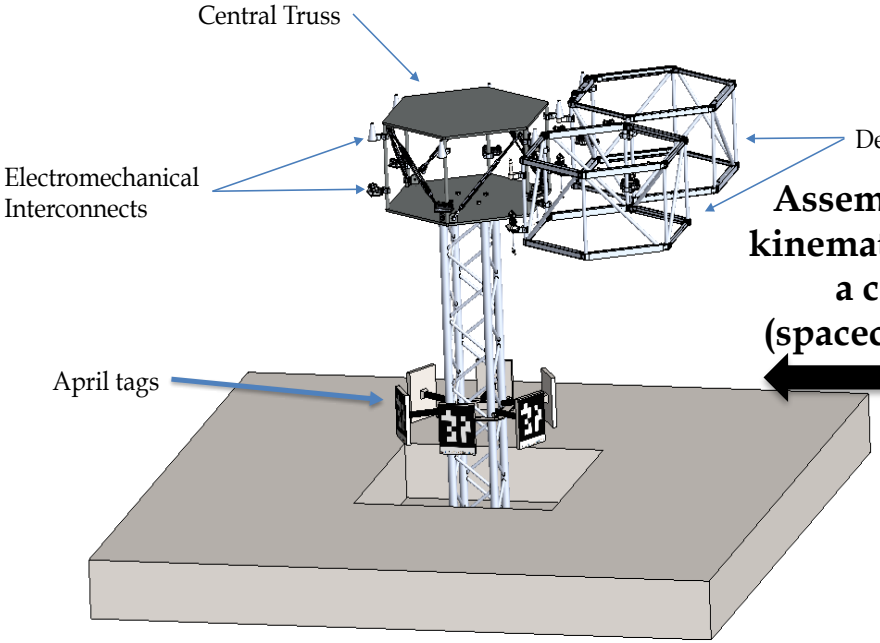
Use adjustable structural and power interconnects



Autonomous mobile manipulation for precision repeated robotic assembly



Assemble 3m closed kinematic truss around a central hub (spacecraft surrogate)



In-Lab Telescope Truss Assembly Robotics

DARPA-funded JPL 3 m telescope assembly demo

In-Space Telescope Assembly Robotics Risk Reduction

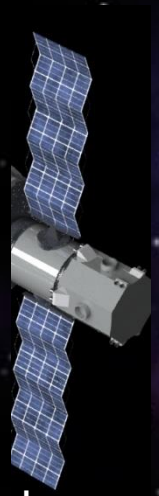
Dr. Rudranarayan Mukherjee (PI), Dr. Paul Backes, Charles Bergh, Jason Carlton, Kyle Edelberg, Blair Emmanuel, Dr. Sisir Karumanchi, Brett Kennedy, Dr. Junggon Kim, Jeremy Nash, Russell Smith

Jet Propulsion Laboratory, California Institute of Technology
Pasadena California 91109 USA

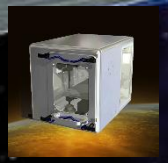
Program Manager: Dr. Lindsay Millard
DARPA Tactical Technology Office

Large Solution Space for In-Space Assembly

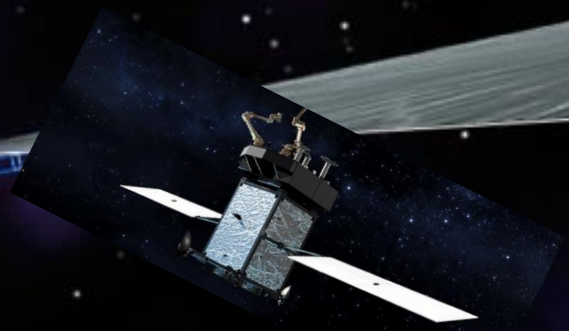
Cis-lunar station



Telescope spacecraft bus



In-space manufacturing



Free-flying servicer

Mobile assembly robot

Fixed assembly robot

Astronaut support

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov